# Dynamic Response of a 2m Diameter Wind Turbine Rotor.

**Olusogo O. Odusote, M.Sc.**

Department of Physics, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria.

E-mail: sog_odusote@yahoo.com

## ABSTRACT

A wind turbine rotor of 2m diameter with three blades was fabricated and analyzed dynamically and on a virtual machine. The coefficient of lift was 0.63 at $10^o$ angle of attack in a free stream of 10m/s. Dynamic test results indicate a coefficient of lift to coefficient of drag ratio of 25 at an aspect ratio of 6.

(Keywords: wind, rotor, turbine, lift, drag, angle of attack, renewable energy)

## INTRODUCTION

The availability of energy is very essential for the wellbeing of humans. Societies have become dependent on energy sources for transportation, manufacturing, heating, ventilation, and air conditioning. Production of energy via fossil resources has led to environmental concerns due to climate change and global warming. Moreover, oil prices are on the increase and the sources are not reliable. This has elicited interest in the production of energy via environmentally friendly and renewable energy sources. Renewable energy comes from natural resources, such as, solar, wind, ocean waves, hydropower, tides, and biomass. It has been reported that in 2008, about 19% of global energy consumption came from renewable sources, with 13% coming from biomass, which is mainly used for heating, and 3.2% from hydropower [1].

Wind energy is rapidly emerging as one of the most cost effective forms of renewable energy with annual growth rate of 30%, and a worldwide installed_capacity of 158GW in 2009. In the U.S. as at the end of 2007, community wind power generation contributed about 2% to electricity generation [2, 3].

Wind power utilizes the kinetic energy of the wind molecules to propel the blades of turbines. These turbines cause the rotation of shafts in alternators, leading to the generation of electricity.

Wind turbines can be separated into two types based on the axis of rotation (i.e., horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT)). They are fabricated to effectively utilize the wind energy that exists at a location. The design and evaluation criteria involve the determination of the optimum tower height, the control systems, number of blades and blade shape. Wind turbines also vary in sizes with a 1.5 MW machine likely to have a tower 80 meters high. Small wind turbines are those smaller than or equal to 100 kilowatts and are used in rural areas, remote monitoring, telecom towers, offshore platforms and other purposes that require energy where there is no electric grid.

The effective operation of the wind turbine depends on the optimal performance of its parts. The rotor is an essential part, and it is of interest to investigate its performance. This work examined the dynamic characteristics of a small turbine in a testing facility without a wind tunnel. The dynamic tests were carried out on a gantry with falling weights used to cause the rotor to spin.

## METHOD

The turbine had three blades made from wood spaced apart on the rotor at $120^o$. Each blade was 80cm long and 15cm wide, with a rectangular plan. The lower airfoil surface was flat and the camber on the top surface was cut with the equation:

$$y = -1E\text{-}10x^6 + 6E\text{-}08x^5 - 1E\text{-}05x^4 + 0.0013x^3 - 0.079x^2 + 2.3589x + 1.4268 \quad \textbf{(1)}$$

where y is the vertical height from the leading edge and x is the horizontal distance from the leading edge.

The resulting blade profile is shown in Figure 1.

**Figure 1:** Profile of the blade

The hub of the rotor was machined from 2mm thick steel plate. The hub consisted of a solid back plate of radius 10cm and a top annulus disc of external radius 10cm and internal radius 8cm. Three hexagonal nuts of size 19mm were placed between the upper and lower plates at 120$^o$ apart and the whole assembly was welded together to form a solid frame. The back plate had a central hole of diameter 1.2cm through which the rotor was mounted on the bearing shaft.

Each blade was mounted on the rotor via a centrally placed rod with the end threaded to screw into the 19mm nut on the hub. The mounted assembly on the gantry is shown in Figure 2. The dynamic response of the rotor was examined on the gantry by setting the rotor into rotation by dropping weights from a string attached to the shaft from a height of 5m. The weights used were of 5Kg and 10Kg with rotation induced in clockwise and anticlockwise directions for the respective weights. The number of rotations from when the weights fell of the shaft (just at the ground level) and when the rotation stopped was counted. This set up is similar to that used in the determination of the moment of inertia of a flywheel.

**Figure 2:** Turbine Mounted on the Gantry.

**THEORY**

For a blade of length c and width b, the planform area $A_p$ is given by:

$$A_p = b.c \tag{2}$$

The coefficients of lift $C_L$ and drag $C_D$ are such that:

$$C_L, C_D = f(\alpha, \text{Re}) \tag{3}$$

$$C_L = \frac{L}{\frac{1}{2}\rho V_\infty^2 A_p} \tag{4}$$

$$C_D = \frac{D}{\frac{1}{2}\rho V_\infty^2 A_p} \tag{5}$$

From Kutta and Joukowski theories [4,5] we have that the magnitude of lift force is:

$$L = \rho\, b V_\infty \Gamma \tag{6}$$

Inviscid mapping theory predicts that [6]:

$$\Gamma_{Kutta} = \pi b c V_\infty (1 + 0.77\frac{t}{c}) \sin(\alpha + \beta) \tag{7}$$

$$\beta = \tan^{-1}(\frac{2h}{c}) \tag{8}$$

In Equation 3 to Equation 8, the following symbols are defined: $h$ is the maximum camber, $\alpha$ is the angle of attack, Re is the Reynold's number, $L$ is the lift force, $D$ is the drag force, $\rho$ is the density of air, $\Gamma$ is the circulation, $t$ is the thickness and $V_\infty$ is the free stream velocity.

For wings of finite span,

$$C_L = \frac{2\pi \sin(\alpha + \beta)}{1 + \frac{2}{AR}} \tag{9}$$

The aspect ratio:

$$AR = \frac{b^2}{A_p} \qquad \textbf{(10)}$$

We have that:

$$L = \frac{1}{4}\pi^2 b.c\rho V_\infty^2 \alpha \qquad \textbf{(11)}$$

$$C_D = \frac{C_L^2}{\pi.AR} \qquad \textbf{(12)}$$

## RESULTS AND DISCUSSION

The results for the number of rotations of the rotor on the gantry for both falling weights and directions are shown in Figure 3.

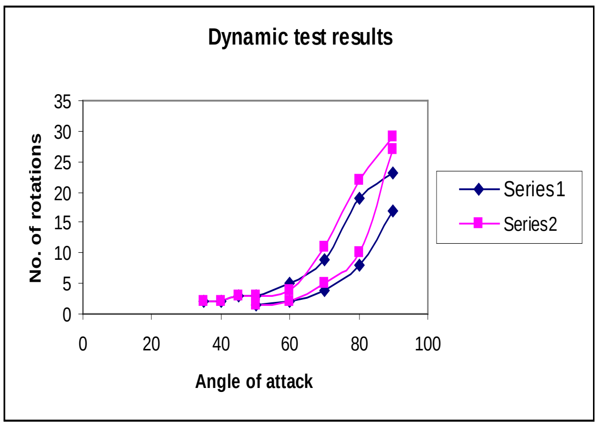


**Figure 3:** Dynamic Response of Rotor.

The series 1 curves are for 5Kg weight while the series 2 curves are for 10Kg weight. The corresponding upper curves in both cases represent anticlockwise rotations, while the corresponding lower curves represent clockwise rotations.

It is observed that there were more rotations in the anticlockwise direction, which corresponded to the direction of rotation of the upper face with the camber. The plan form areas presented to the windstream were the same in both directions of rotation. Hence, it could be concluded that the turbine blades produced lift. Simulation in a virtual environment gave the coefficient of lift as 0.63 at a wind speed of 10 m/s, at an angle of attack of $10^o$ and a lift to drag ratio of 25 was obtained.

Although this ratio indicates that lift was produced, modern day rotors are desired to produce higher ratios. The drawback in this design was the use of wood as the blade material. It is envisaged that if flat steel sheet is used to fabricate the blades, the camber could be reduced, which would give rise to a more streamlined flow over the blades.

The camber and thickness of the wood blades were large so as to afford structural rigidity.

## CONCLUSION

The response of the rotor of a small wind turbine was investigated. Since specialized and dedicated with tunnel facilities are not readily available, a test gantry was used for the study. This gantry test indicated the production of lift.

Further work is ongoing to be able to assign quantitative values to the lifts produced by tests on the gantry. This would afford the work of researchers in areas where wind tunnels are not available.

## REFERENCES


1. REN21. 2010. “Renewables 2010 Global Status Report”. 15-16.

2. Wiser, R. and M. Bolinger. 2008. “Annual Report on U.S. Wind Power Installation, Cost and Performance Trends 2007”. US Department of Energy, Energy Efficiency and Renewable Energy: Washington, D.C.

3. Mazza, P. 2008. “Community Wind 101: A primer for Policymakers”. http://www.harvestcleanenergy.org/.

4. Kutta, W. 1902. “Auftriebkrafte in stromende Flussigkeiten, III”. *Aeronaut. Mitteilungen*, July.

5. Joukowski, N. 1906. *Bull. De I’Inst. Aeronaut. Koutchino*. Fasc. I, St. Petersburg.

6. White, F.M. 1974. *Viscous Fluid Flow*. McGraw-Hill: New York, NY.

## ABOUT THE AUTHOR

**Olusogo Odusote,** is a Lecturer at the Olabisi Onabanjo University, Nigeria. He is a physicist and is a member of the Nigerian Association of Mathematical Physics. He holds a Master of Science (M.Sc.) in Physics from the University of Jos. His research interest is in condensed matter physics.

## SUGGESTED CITATION

Odusote, O.O. 2012. "Dynamic Response of a 2m Diameter Wind Turbine Rotor". *Pacific Journal of Science and Technology*. 13(2):103-106.

Pacific Journal of Science and Technology